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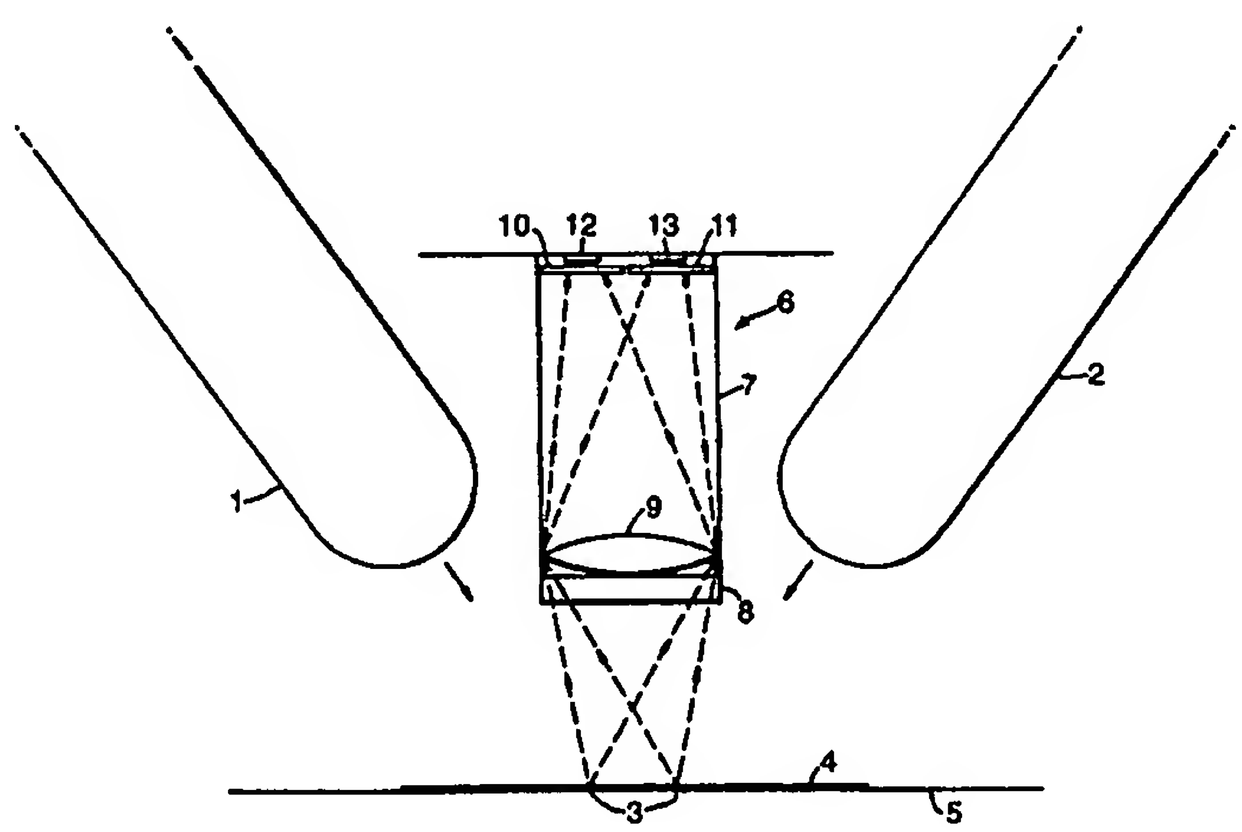

(57) Abstract

A method and apparatus for monitoring articles to determine the presence of an authenticity indicating characteristic. The method comprises irradiating an article with radiation in at least first and second wavebands; detecting first radiation generated by the article in response to irradiation at the first waveband, the first waveband being chosen such that the first radiation generated varies in accordance with the presence or absence of the authenticity indicating characteristic and in response to the presence of obscuring material on the article. Second radiation generated by the article in response to irradiation at the second waveband is detected, the second waveband being chosen such that the second radiation generated by the article varies with the degree of obscuring material on the article but is substantially independent of the presence of the authenticity indicating characteristic. The detected radiations are compared to determine whether or not the authenticity indicating characteristic is present.

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METHODS AND APPARATUS FOR MONITORING ARTICLES

The invention relates to methods and apparatus for monitoring articles, for example documents of value such as banknotes.

The principle of using reflectance measurements to authenticate security documents is well known. The characteristics of security paper are such that in some regions of the spectrum (UV, visible and IR), the reflectivity is different from that of many non-security papers used for producing counterfeit documents.

For example, a simple authentication system can be produced by illuminating a document with UV light and measuring the intensity of the reflections. If this intensity exceeds a predetermined threshold level, the document is deemed to be authentic. (Note, however, that in specific situations, it may be the counterfeit document that has the higher reflectivity.) It is possible to carry out a measurement of the natural UV-excited fluorescence of the paper at the same time: most security papers have a low level of natural fluorescence. This "UV Bright" measurement technique is also well known.

The simple techniques outlined above have several disadvantages in any practical implementation. The two most important are:

- The intensity of the reflections from any given document is also dependent on the characteristics of the measurement system, some of which can vary significantly. For example, the output intensity of most UV sources varies with temperature, and as the source ages. The characteristics of the optical components used (filters, windows, lenses, etc.) can also change as they age. Dirt and dust build-up on the optical surfaces during use reduce the measured intensity.

- The intensity of the reflections is dependent on the soiling of the document: the dirtier the document, the lower the reflectivity.

Changes in the sensitivity of the measurement system may be reduced with an automatic calibration system that continually monitors the signal level measured on a reference surface, but there are difficulties and costs in providing a continuously clean reference surface. Such a system cannot, of course, compensate any soiling of the documents.

The combined effect is to reduce the discrimination of the detection system. If the detection threshold is set sufficiently high to detect the cleanest counterfeit with a new, clean (high sensitivity) system, a relatively large fraction of dirty, genuine notes will be falsely deemed counterfeit; this fraction will increase as the detection system ages or becomes dirty. If the threshold is decreased so that only a small fraction of genuine notes is falsely deemed counterfeit by an old, dirty (low sensitivity) system, an unacceptably large fraction of counterfeits will be deemed to be genuine by a clean system.

US-A-4723072 describes apparatus for measuring the soiling of banknotes, using one or more sensors working in the same optical waveband. The present invention is not concerned with measuring soiling.

US-A-3679314 describes apparatus for optically testing the genuineness of banknotes by successively illuminating a selected portion of a note with lightbeams having different spectral distributions and then detecting the light transmitted through or effected by the illuminated portion. The problem with this approach is the need to scan a pair of filters mechanically across the illumination beam in order to control the illumination of the banknote.

In accordance with one aspect of the present invention, a method of monitoring articles to determine the presence of an authenticity indicating characteristic

comprises irradiating an article with radiation in at least first and second wavebands; detecting first radiation generated by the article in response to irradiation at the first waveband, the first waveband being chosen such that the first radiation generated varies in accordance with the presence or absence of the authenticity indicating characteristic and in response to the presence of obscuring material on the article; detecting second radiation generated by the article in response to irradiation at the second waveband, the second waveband being chosen such that the second radiation generated by the article varies with the degree of obscuring material on the article but is substantially independent of the presence of the authenticity indicating characteristic; and comparing the detected first and second radiation to determine whether or not the authenticity indicating characteristic is present.

In accordance with a second aspect of the present invention, apparatus for monitoring articles to determine the presence of an authenticity indicating characteristic comprises at least one source for irradiating an article with radiation in at least first and second wavebands; a first detector for detecting first radiation generated by the article in response to irradiation at the first waveband, the first waveband being chosen such that the first radiation generated varies in accordance with the presence or absence of the authenticity indicating characteristic and in response to the presence of obscuring material on the article; a second detector for detecting second radiation generated by the article in response to irradiation at the second waveband, the second waveband being chosen such that the second radiation generated by the article varies with the degree of obscuring material on the article but is substantially independent of the presence of the authenticity indicating characteristic; and comparison means for comparing the detected first and second radiation to determine whether or not the authenticity indicating characteristic is present.

We have found that it is possible to distinguish between authentic and non-authentic articles even where these carry obscuring materials such as soiling by irradiating the articles in at least two different wavebands which have the characteristics specified above.

Typically, the first waveband will lie outside the visible wavelength range, for example in the ultraviolet or infrared range. Indeed, in principle, the illumination could be anywhere in the electro-magnetic spectrum. This is often important since the authenticity characteristic will not generally be visible within the visible wavelength range as it is a covert feature. However, the second waveband will often be in the visible wavelength range since in this range it will not be substantially affected by the authenticity characteristic. In some cases, however, both wavebands can lie in or outside the visible wavelength band.

Provided the first and second wavebands are close together, soiling has substantially the same effect on radiation in both wavebands. Thus, the relationship between the first and second detected radiation will be substantially the same irrespective of the degree of soiling (at least up to some limit). This then provides a very convenient way of distinguishing between genuine and counterfeit banknotes, for example, where the relationship between the first and second radiation will differ depending upon the authenticity and not on the amount of soiling.

Although separate sources could be used, a particularly convenient aspect of the invention is that it enables a single source to be used which generates radiation in both or all wavebands. For example, some conventional UV sources generate radiation in the UV waveband and also in the visible region. For simplicity, we will refer hereafter to the use of UV radiation but it should be understood that other wavelengths, single or multiple, could be used instead.

The irradiation at all wavebands and selective detection, rather than irradiating at selected wavebands, avoids the need for mechanical scanning, reduces the susceptibility to stray light, and simplifies processing. Conveniently, this is achieved by positioning filters in front of the detectors.

Although it has been found that usually two first wavebands is sufficient, irradiation at more than two wavebands could be carried out. In some cases, this will lead to a more accurate determination of authenticity.

For example, in an embodiment where irradiation at three wavebands is used, two of the three wavebands are normally selected so that they are at regions where the generated radiations varies with the presence or otherwise of a respective one of two authenticity indicating characteristics and with the degree of obscuring material. The third waveband is at a region where the generated radiation varies with the degree of obscuring material, but does not vary substantially with the presence or otherwise of the two authenticity indicating characteristics.

Typically, the first and second detected radiation generated by the article will comprise reflected radiation, the wavelengths of the reflected radiation depending on the characteristics (print, paper, etc.) of the article. In some cases, the irradiation will also cause the print or the paper of the article to luminesce. It would be possible to distinguish between fluorescence and phosphorescence by suitably modulating the irradiation in known manner. Modulation can also be used to eliminate the affects of ambient light.

The first and second detected radiation will typically lie within the first and second wavebands respectively. However, in some cases, one or both of the first and second detected radiation may be offset in wavelength from the corresponding irradiation.

The relationship between the first and second detected radiation can be determined in a variety of ways. In one

approach, the ratio of the intensity of the first and second detected radiation is determined. That ratio can then be compared with a predetermined threshold to determine whether or not the article is genuine. In another approach, a number of different characteristics of the first and second detected radiation can be determined from which a measurement vector is constructed for comparison with one or more measurement vectors corresponding to a genuine and/or known counterfeit article.

It will be appreciated that an important application of the invention is in the monitoring of documents of value such as banknotes but the invention is also applicable to monitoring other types of article, particularly those printed with inks which respond in both the visible and non-visible wavebands.

Some examples of methods and apparatus according to the invention will now be described with reference to the accompanying drawings, in which:-

Figure 1 is a schematic view of a first example of the apparatus;

Figure 2 is a block circuit diagram showing the lamp control circuit;

Figure 3 is a block diagram illustrating the processing circuit;

Figure 4 illustrates graphically the typical output spectrum of an unfiltered UV source;

Figure 5 illustrates graphically the characteristics of a pair of optical filters that may be used to determine the characteristics of the two second wavebands. (It should be recognised that this particular pair of filters is only given as an example, and that other pairs or multiple filters may be more suited to some applications);

Figure 6 is a schematic block diagram of a second example of the apparatus; and,

Figure 7 illustrates the wavebands used with the apparatus of Figure 6.

The apparatus shown in Figure 1 comprises a pair of UV lamps 1,2 mounted at an angle so that radiation generated by the lamps is directed to a region 3. The region 3 is located in the path of banknotes 4 which are carried through the region 3 on a moving conveyor 5 such as a belt. Each lamp generates a range of wavelengths typically as shown in Figure 4. In particular, it will be noted that a relatively high intensity radiation is generated within a first waveband - the UV band (wavelengths less than about 380nm) and within a second waveband - the visible range (380-700nm). To a first approximation, the overall shape of this spectrum will not change significantly with temperature, or as the lamp ages, even if the total integrated output changes.

Radiation generated by the lamps 1,2 will be reflected by the banknote, the (first and second) wavelengths of the reflected radiation being dependent on the inks on the banknote and the banknote paper. The intensity of the reflected UV radiation responds to the authenticity of the inks or the banknote paper, and to the degree of soiling. The intensity of the reflected visible radiation is dependent substantially solely on the degree of soiling. The radiation may also stimulate inks on the banknote 4 to luminesce. The reflected radiation and luminescence is received by a focusing and detection system 6. The system 6 includes a tubular housing 7 at the leading end of which is mounted an infrared stop filter 8 and a focusing lens 9 which focuses the incoming radiation onto a UV pass filter 10 and a visible pass filter 11 whose characteristics are shown in Figure 5. Respective sensors 12,13 are mounted behind the filters 10,11. The sensor 12 thus provides an output indicative of the intensity of incident UV light while the sensor 13 provides an output indicative of the intensity of incident visible light.

In one preferred approach, the intensities of the detected radiation are simply compared, for example by taking their ratio, and this ratio is then compared with a

predetermined threshold to determine whether or not the banknote is genuine. For example, a genuine banknote may have a visible reflection which is high compared with the UV reflection in contrast to a counterfeit in which the intensities at the two wavebands are similar. If the ratio exceeds the threshold then this will be indicative of a genuine note, i.e. a relatively large difference in intensity of reflection at the two wavebands.

As mentioned previously, certain inks can luminesce upon irradiation at one or both of the wavebands. In addition, the sensors may receive and respond to ambient light. In the preferred approach, therefore, the lamps 1,2 are modulated so that a distinction can be made between ambient light on the one hand and light received in response to irradiation on the other hand, although this is not an essential part of the invention.

Figure 2 illustrates a simple circuit for modulating the lamp output, the circuit comprising a clock generator 20 which is connected to a lamp control circuit 21 which in turn is connected to the lamps 1,2.

Each sensor 12,13 is coupled to a respective amplifier 30. The outputs of the two amplifiers are fed to respective Signal Processing Circuits 31,32. These process the signals to produce a number of Signal Measures, quantities related to different characteristics of the amplifier outputs. The Signal Processing Circuits may include low-pass filters, high-pass filters, demodulators, integrators, and other techniques well known to those skilled in the art. The measures include differently filtered versions of the amplifier outputs, etc. and combinations of these (sums, differences, quotients, etc.). In general, these Signal Processing Circuits will have no storage capability, and the measures will vary as the amplifier outputs vary, apart from the relatively short delays inherent in the processing. Such signal processing may be carried out using analogue or digital electronic

hardware 33, or using software techniques, as is convenient.

Typical information which can be obtained from the sensors 12,13 includes:

(a) Level of modulation of detected UV light;

(b) Average, or DC, level of detected UV light;

(c) Level of modulation of detected visible light;

(d) Average, or DC, level of detected visible light.

These can be used to obtain certain measures.

Often the most important measure is the ratio (a):(c), but (b) and (d) can also provide some useful information. As the UV channel is sensitive to a range of wavelengths, the output (b) can contain a contribution from any "long" UV wavelength phosphorescence induced by the "short" UV wavelength illumination. The measure of this "UV phosphorescence" is given by the difference between output (b) and output (a). Similarly, the difference between outputs (d) and (c) is a measure of any visible phosphorescence.

The measures are fed to the Measure Analysis Circuitry 33, which also may have other external signal inputs (threshold levels, positional information from the document transport system, etc.). This circuitry processes the measurements individually or in combination to produce a single output signal that indicates whether or not the banknote is genuine.

The processing may be relatively simple, comprising comparisons of signal levels with threshold levels, and a comparison of the measures representative of reflections in the two second wavebands, as discussed above. In some cases it has been found that more complex techniques, such as processing several measures together, treating them as a single measurement vector rather than independent measurements, and using multi-dimensional clustering techniques to define the characteristics of genuine and known counterfeit notes can allow a high proportion of counterfeits to be identified. Such processing is normally

carried out using standard mathematical and software techniques, including the use of Artificial Neural Nets.

These measurements may be made at one position on a document, or at a number of positions as the document is passed through a transport system past the detector. Such techniques are well known to those skilled in the art.

The response of the UV pass filter 10 is chosen so that measurements are made at part of the UV spectrum where the difference of the reflectivities of genuine and counterfeit documents are greatest. The response of the visible pass filter 11 is chosen so that measurements are made at a region where there is a significant visible output.

In the example described above, two wavebands were used. Figure 6 illustrates apparatus in which radiation from the document in three wavebands is detected. The circuit shown in Figure 6 is very similar to that shown in Figures 2 and 3 and this circuit would be used with an arrangement similar to that shown in Figure 1. In this case, a pair of lamps 101,102, typically in the form of discharge lamps containing gas such as neon are used to irradiate the document. Each lamp generates radiation in a number of narrow peaks at wavelengths from below 330nm to above 800nm although other wide band sources could be used. The lamps are controlled by a lamp control circuit 103 coupled with a clock 104. Radiation from the document is passed to three photodiodes 105-107 via respective filters 108-110. The pass bands of these filters are shown in Figure 7 where it will be seen that these pass bands are non-overlapping. The pass band for the filter 108 is shown at 111, the pass band for the filter 109 is shown at 112, and the pass band for the filter 110 is shown at 113.

The output signals from the photodiodes 105-107 are amplified by respective amplifiers 114-116 and passed to respective signal processing circuitry 117-119. The signals are then passed to analysis circuitry 120 similar to the circuitry 33 shown in Figure 3.

When irradiation is measured in three (or more) wavebands, the simplest form of processing is to calculate the ratios of the intensities in each of the wavebands 111-113 where the generated radiation varies with the presence or otherwise of authenticity indicating characteristics to the intensity in the waveband where the generated radiation varies with the degree of obscuring material, but not substantially with the presence or otherwise of the authenticity indicating characteristics. These ratios are then compared to predetermined threshold values to determine whether the article is genuine. However, it is usually more advantageous in this case to use a technique in which a measurement vector is constructed from several different characteristics of the detected radiations, and then this measurement vector is compared with one or more measurement vectors corresponding to genuine and/or counterfeit articles.

The invention is applicable to many different forms of article monitoring system including document sorters and acceptors, and cash handling equipment such as counters, sorters, dispensers and acceptors. The invention is particularly suited to the monitoring of banknotes.

CLAIMS

1. A method of monitoring articles to determine the presence of an authenticity indicating characteristic comprises irradiating an article with radiation in at least first and second wavebands; detecting first radiation generated by the article in response to irradiation at the first waveband, the first waveband being chosen such that the first radiation generated varies in accordance with the presence or absence of the authenticity indicating characteristic and in response to the presence of obscuring material on the article; detecting second radiation generated by the article in response to irradiation at the second waveband, the second waveband being chosen such that the second radiation generated by the article varies with the degree of obscuring material on the article but is substantially independent of the presence of the authenticity indicating characteristic; and comparing the detected first and second radiation to determine whether or not the authenticity indicating characteristic is present.

2. A method according to claim 1, wherein the first waveband is outside the visible wavelength region.

3. A method according to claim 1 or claim 2, wherein the second waveband is in the visible wavelength range.

4. A method according to any of the preceding claims, wherein the first detected radiation is outside the visible wavelength range.

5. A method according to any of the preceding claims, wherein the second waveband is in the visible wavelength band.

6. A method according to any of the preceding claims, wherein the first radiation falls substantially within the first wavelength band.

7. A method according to any of the preceding claims, wherein the second radiation falls substantially within the second wavelength band.

8. A method according to any of the preceding claims, wherein the radiation in at least one of the first and second wavebands is reflected by the article to constitute at least part of the first and second detected radiation respectively.

9. A method according to any of the preceding claims, wherein the detected radiation includes luminescence.

10. A method according to any of the preceding claims, further comprising modulating the irradiating radiation and detecting radiation received with substantially no modulation and/or with a similar modulation.

11. A method according to any of the preceding claims, wherein the comparison step comprises determining the ratio between the intensities of the first and second detected radiation.

12. A method according to any of the preceding claims, further comprising determining the relationship of the result of the comparison step with an expected relationship corresponding to an acceptance condition.

13. A method according to claim 12, when dependent on claim 11, wherein the relationship determining step comprises comparing the ratio with a threshold.

14. A method according to any of the preceding claims, wherein the irradiation is generated from a single source.

15. A method according to any of the preceding claims, wherein radiation in at least three wavebands is detected.

16. A method according to any of the preceding claims, wherein the article comprises a sheet such as a document of value, for example a banknote.

17. Apparatus for monitoring articles to determine the presence of an authenticity indicating characteristic comprises at least one source for irradiating an article with radiation in at least first and second wavebands; a first detector for detecting first radiation generated by the article in response to irradiation at the first waveband, the first waveband being chosen such that the first radiation generated varies in accordance with the

presence or absence of the authenticity indicating characteristic and in response to the presence of obscuring material on the article; a second detector for detecting second radiation generated by the article in response to irradiation at the second waveband, the second waveband being chosen such that the second radiation generated by the article varies with the degree of obscuring material on the article but is substantially independent of the presence of the authenticity indicating characteristic; and comparison means for comparing the detected first and second radiation to determine whether or not the authenticity indicating characteristic is present.

18. Apparatus according to claim 17, wherein the first and second sources are formed by a common source.

19. Apparatus according to claim 17 or claim 18, adapted to carry out a method according to any of claims 1 to 16.

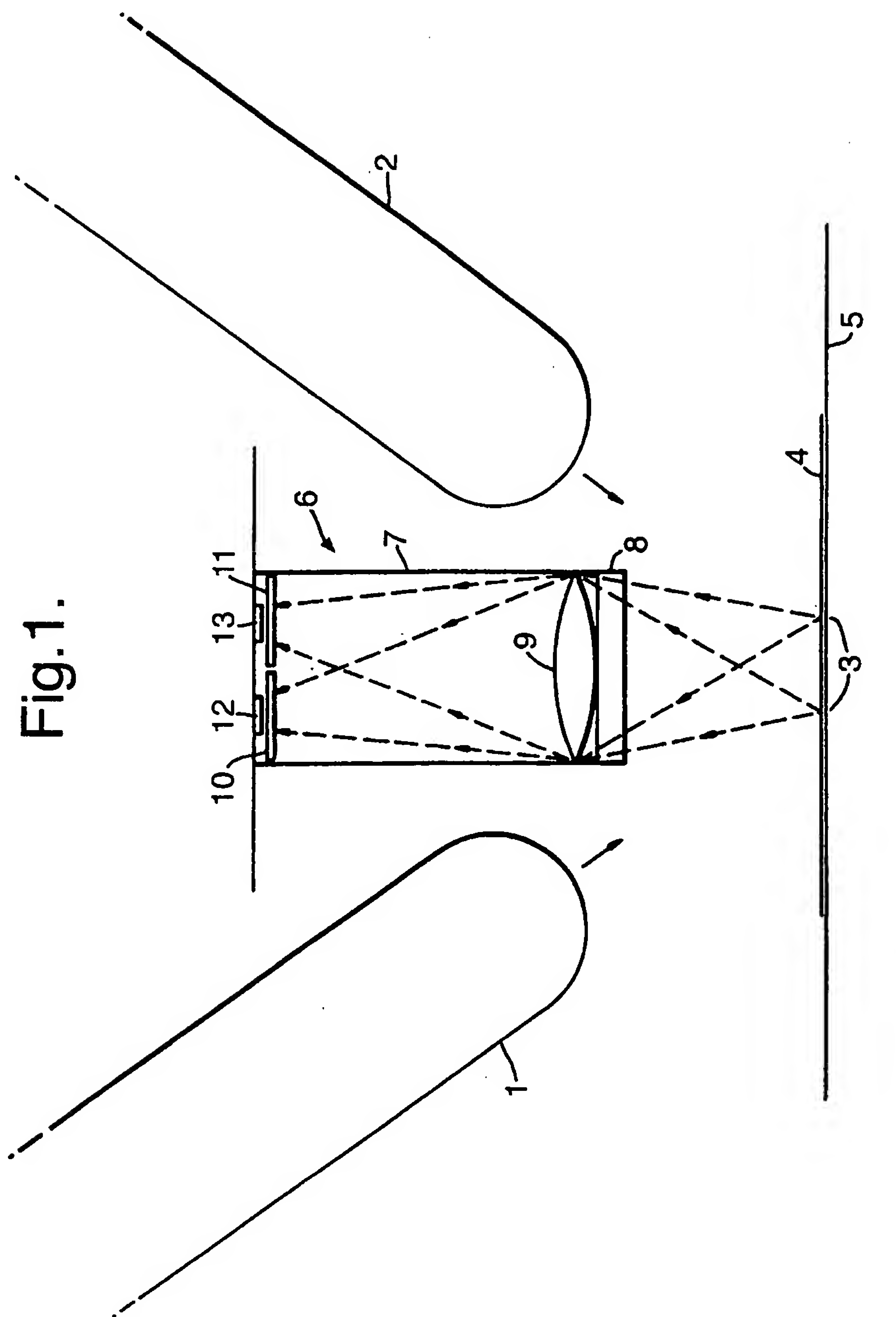
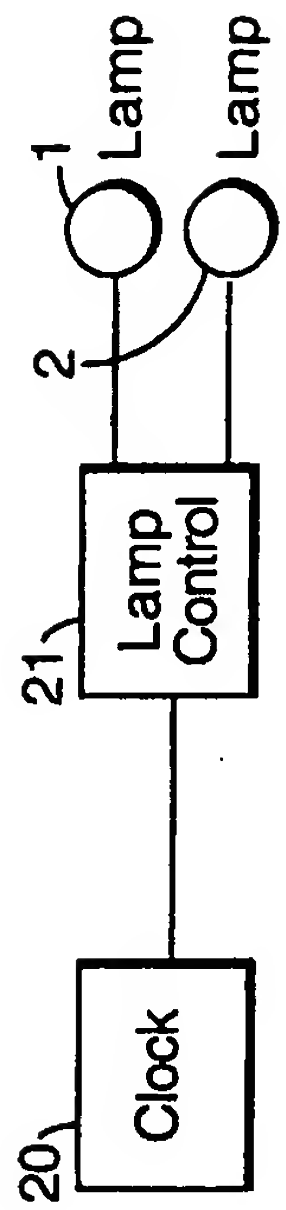


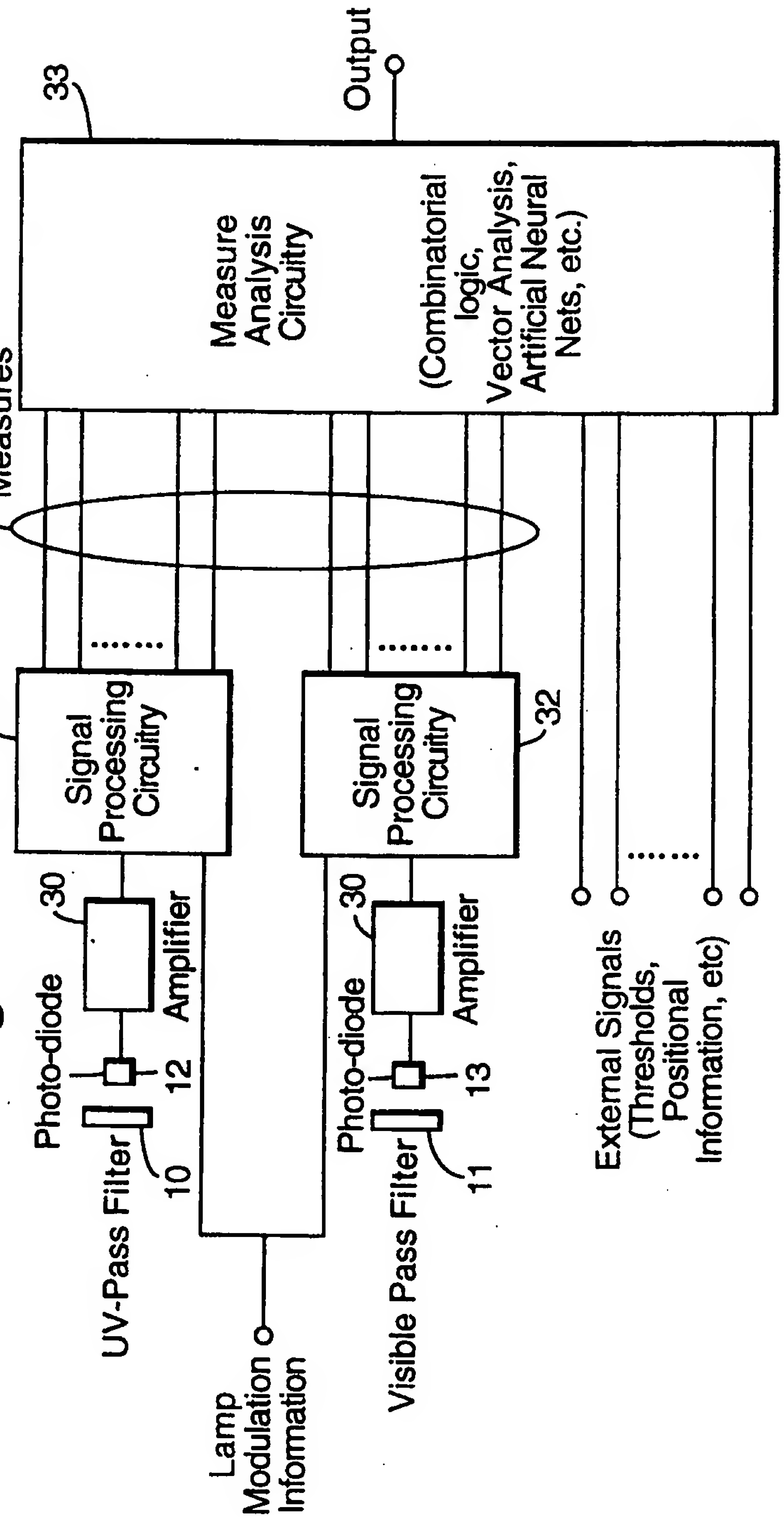
Fig.1.

Fig.2.



Clock
20
Lamp Control
21
2
1
Lamp
Lamp

Fig.3.



UV-Pass Filter
10
Photo-diode
12
30
Amplifier
Signal Processing Circuitry
31
Visible Pass Filter
11
Photo-diode
13
30
Amplifier
Signal Processing Circuitry
32
Lamp Modulation Information
Signal Measures
Measure Analysis Circuitry
(Combinatorial logic, Vector Analysis, Artificial Neural Nets, etc.)
33
Output
External Signals (Thresholds, Positional Information, etc)

Fig.4.

Typical Output of Unfiltered UV Source

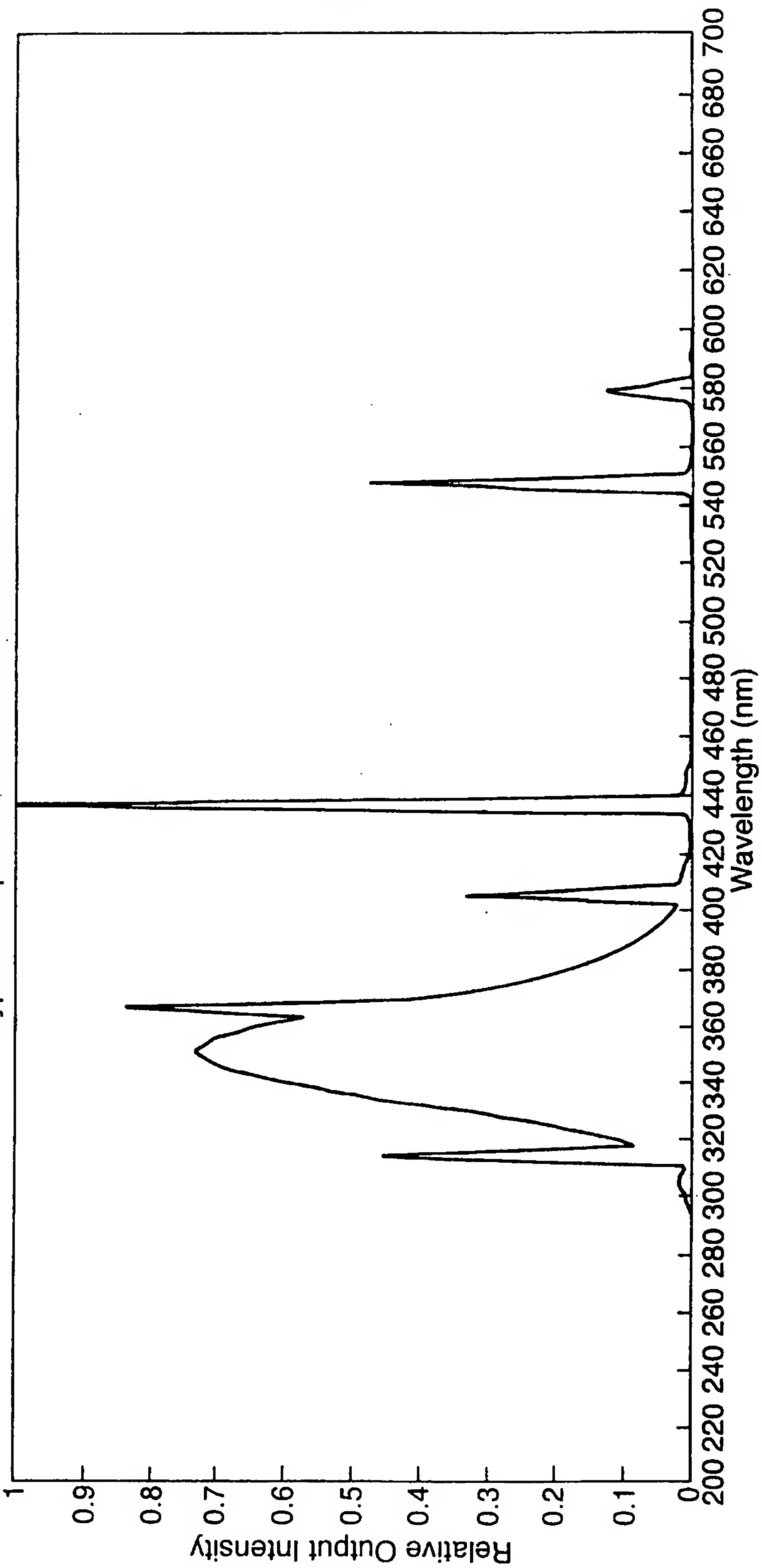
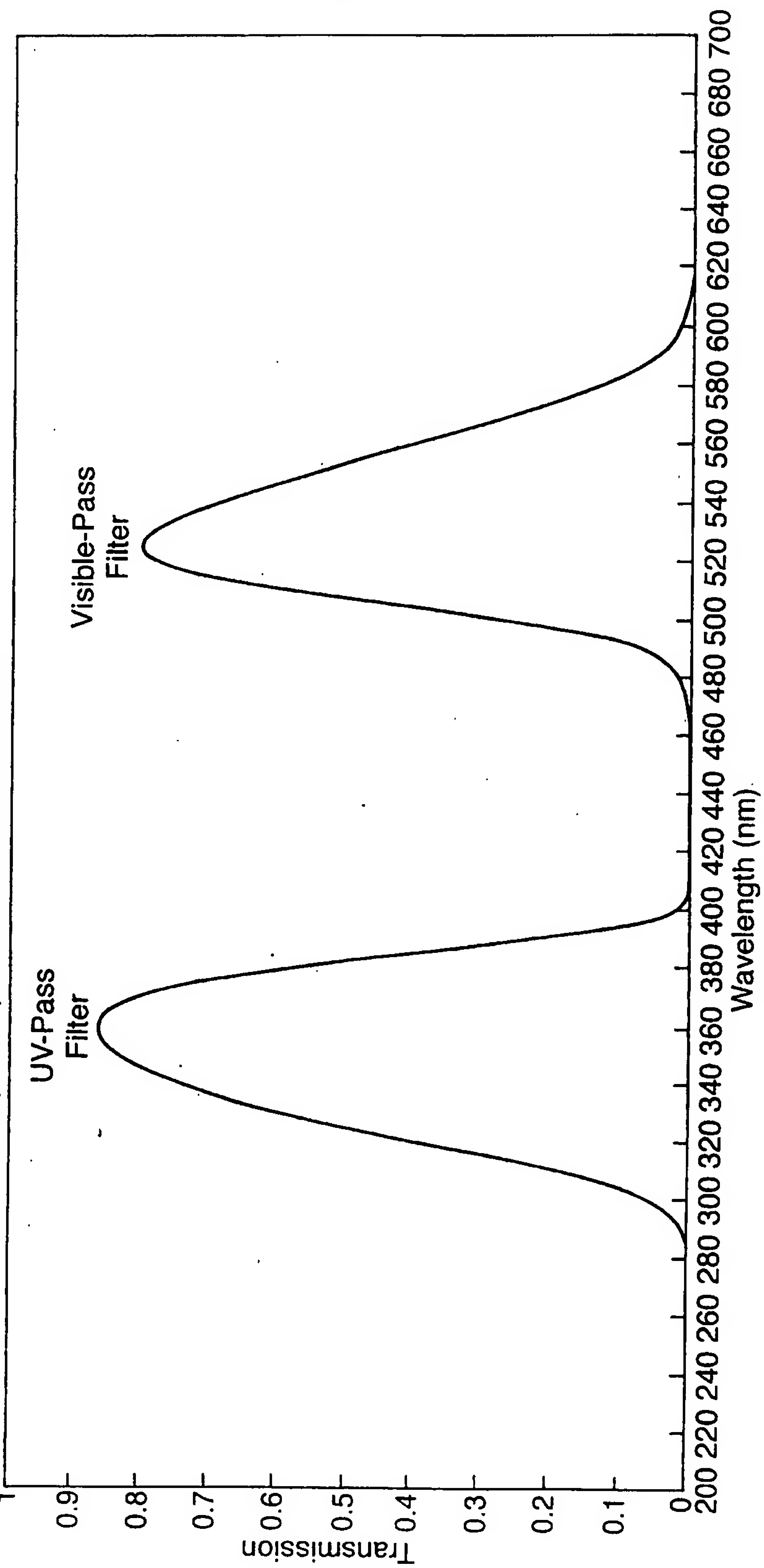


Fig.5.

Typical Optical Filter Characteristics



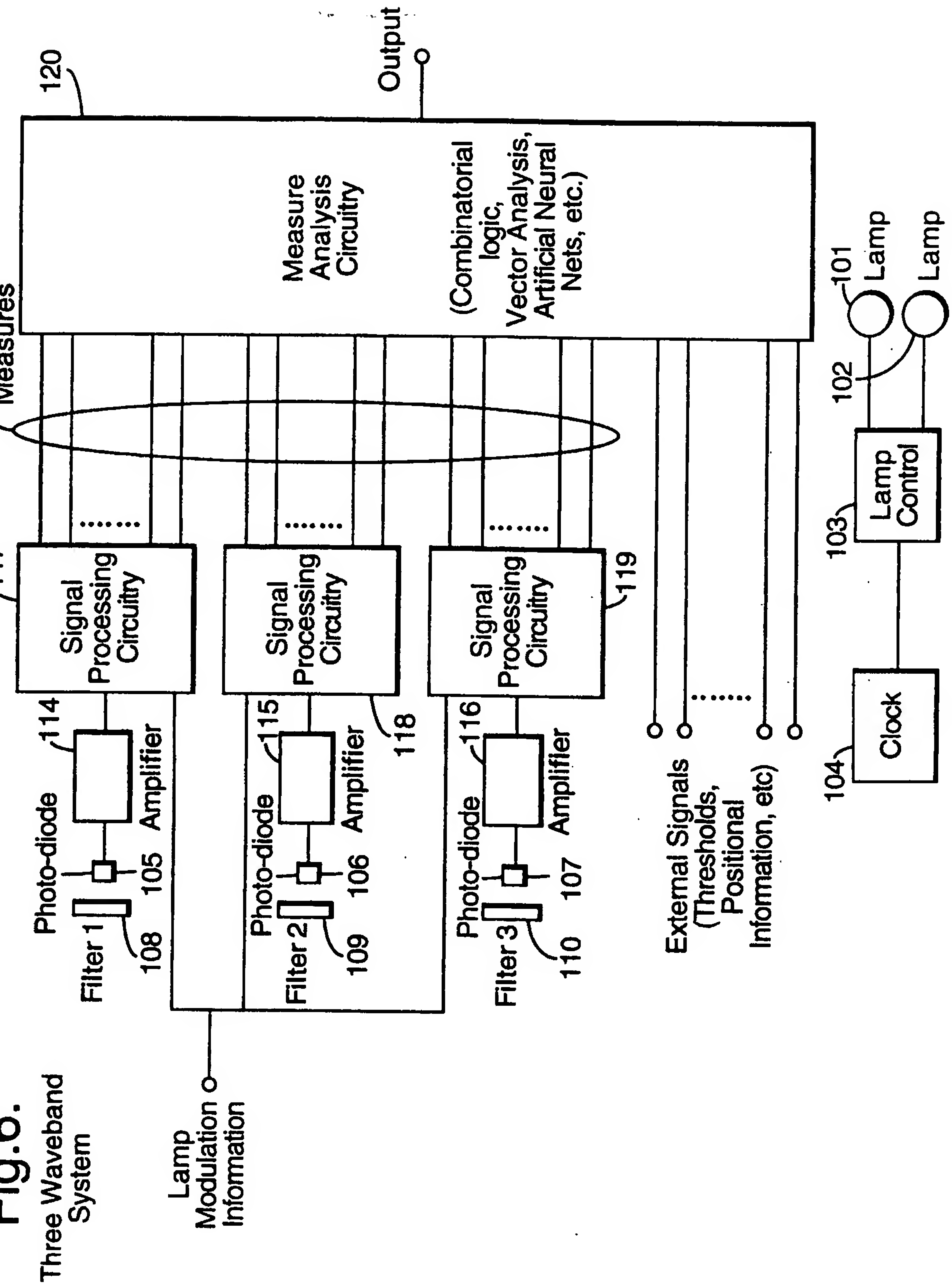
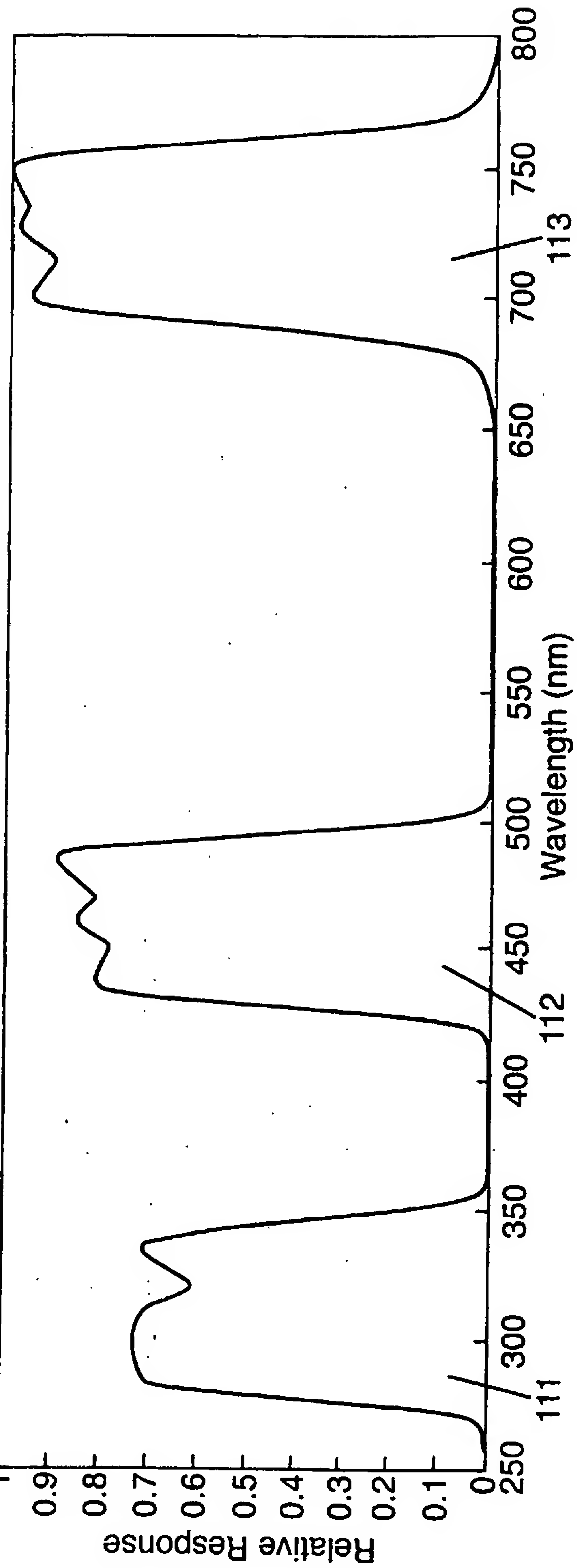


Fig.6. Three Waveband System

Fig.7.

Irradiation at Three Wavebands-A Possible Set of Filters



INTERNATIONAL SEARCH REPORT

Inte .onal Application No
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A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G07D7/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 G07D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4 723 072 A (NARUSE KAZUAKI) 2 February 1988 (1988-02-02) claim 1; figure 8 ---	1-19
A	US 3 679 314 A (MUSTERT RUDOLF) 25 July 1972 (1972-07-25) claim 1; figure 1 ---	1-19
A	US 4 592 090 A (CURL BARRY J ET AL) 27 May 1986 (1986-05-27) claim 1; figure 1 ---	1-19
A	US 5 437 357 A (OTA MICHIHIRO ET AL) 1 August 1995 (1995-08-01) claim 1; figure 4 ---	1-19

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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